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O B S E R V A T I O N S
ON
BITUMINOUS SUBSTANCES,
WITH
A DESCRIPTION
OF THE
VARIETIES OF THE ELASTIC BITUMEN.

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IX. *Observations on Bituminous Substances, with a Description of the Varieties of the Elastic Bitumen.* By Charles Hatchett, Esq. F. R. S. Lond. and Edinb. F. L. S. &c.

Read May 2, June 6, and July 4, 1797.

§ 1.

IT is now generally believed that the bituminous substances are not of mineral origin, but that they have been formed from certain principles of substances belonging to the organized kingdoms of Nature, which, after the loss of animal and vegetable life, have suffered considerable changes by long contact and union with mineral bodies.

These changes have been however so considerable, that the bitumens can no longer be referred to their first origin, and they are therefore regarded by general consent as forming part of the present mineral system.

The bituminous substances are :

Naptha,

Petroleum,

Mineral Tar,

Mineral Pitch,

Asphaltum,

Jet,

Jet,
Pit Coal,
Bituminous Wood,
Turf,
Peat, and

those combinations of the oxides of certain metals with bitumen called Bituminous Ores*.

Those who are acquainted with the nature of these substances will immediately perceive, that they may be formed into two divisions: the first of which consists of simple species, or unadulterated bitumens: and the second is composed of bitumen mixed or combined with the earths, vegetable matter, and metallic oxides; so that these appear to merit the name of compound species.

I shall now first consider how the simple species are connected with each other.

§ 2.

IT has been the opinion of some eminent Naturalists and Chemists, that naptha is an ethereal oil produced from the more compact and solid bitumens by a sort of natural distillation. This however appears to be an hypothesis founded upon analogy, and supported only by a few local facts which may often be questioned. But many facts and observations concur to prove that the contrary most frequently happens, and that the compact bitumens are often, if not always, formed from naptha and petroleum by inspissation. I will not however now insist upon the proofs of this, as the varie-

* As I intend only here to notice the modifications of naptha and petroleum, I have not mentioned amber and the honey-stone.

ties of the elastic bitumen, which I shall soon describe, will be sufficient for the purpose*.

NAPTHA.

NAPTHA is a substance well known to Mineralogists as a light, thin, often colourless oil, highly odoriferous and inflammable, which is sometimes found on the surface of the waters of springs, and at other times issuing from certain strata.

When exposed to the air, it becomes at first yellow, afterwards brown, and in the like proportion it thickens, and passes into

PETROL OR PETROLEUM.

THIS has a greasy feel, is thicker than the preceding substance, is transparent or semitransparent, and of a reddish or blackish brown colour. By air it becomes like tar, and then is called

MOUNTAIN OR MINERAL TAR, BITUMEN PETROLEUM TARDE FLUENS.

THIS substance is viscid, and of a reddish or blackish brown or black. When burned, it emits a disagreeable bituminous smell, and by exposure to the air it passes into

* Bergman was of opinion, that the liquid bitumens were often, if not always, formed from those which are solid, by the means of subterraneous heat; and expresses himself thus: "Cæterum ad fidem pronum est, naphani, petroleum, bituminososque liquores, quibus abundat Asia, plures harum materierum exhibens non tantum scaturigines, sed rivulos quoque, quibus etiam, parcius licet distributis, Australis Europa non caret; probabile, inquam, est, has pinguedines liquidas variis antea terris inhæsisse exsiccatas, et mediante calore subterraneo, si non semper, sæpe tamen fluiditatem recuperasse. Novimus ignem in alto haud raro agere, quamvis in superficie vix obscura ejusdem indicia investigare liceat: novimus præterea e sicco aluminari schisto petroleum extorqueri justo caloris gradu, cui arte exponitur.—*Bergman de Productis Vulcaniis Opuscula*, tom. iii. p. 238.

MOUNTAIN OR MINERAL PITCH—BITUMEN MALTHA.

THE mineral pitch much resembles common pitch, and, when heated, emits a strong unpleasant odour, like the former substance. When the weather is cold, it may be broken, and then exhibits, internally, a glassy lustre; but when warm, it is softened, and possesses some tenacity. It is however susceptible of a superior degree of induration, and then becomes

ASPHALTUM—BITUMEN ASPHALTUM—PETROLEUM
INDURATUM.

THIS is a light, brittle substance, of a brownish black, or black. When broken, it shews a conchoidal fracture with a glassy lustre. It has little of the bituminous odour, unless it is rubbed or heated. It easily melts, is very inflammable, and, when pure, burns without leaving any ashes.

In this manner, naptha, by inspissation, passes successively through different states until it becomes asphaltum, which appears to be the ultimate degree of induration which the pure bitumens derived from naptha can receive.

I have at this time specimens before me which prove these gradations; and I have seen a remarkable instance in a bitumen brought from the Island of Trinidad, which exhibits mineral tar passing into mineral pitch, and lastly into asphaltum*.

§ 3.

* The progressive changes of naptha into petroleum, mineral tar, mineral pitch, and asphaltum, appear to be caused by the gradual dissipation of part of the hydrogen of the bitumen, and the consequent development or disengagement of carbon. Hence, I am inclined to believe, arise the changes of colour, the degrees of inspissation, and the increased proportion of carbon found in those substances by chemical analysis.

I would

§ 3.

THE division which comprehends the simple bituminous substances derived from naphtha, may therefore be considered as terminating in asphaltum; but Nature appears to have glided on by an uninterrupted chain which connects the simple bitumens with those which we have called compound; and this effect is produced by the gradual increase of the carbonic principle, and the introduction of extraneous matter, the different quantity of which, together with the greater or less degree of mixture or of chemical union, occasion considerable changes in these substances, so that they are gradually removed from those characters which distinguish the pure bitumens.

To form an accurate table of these gradations, it would be necessary to have comparative analyses of the different bituminous substances, and also to contrast the analyses with the properties of these bodies. But at present these analyses, for the greater part, are wanting; and although at some future time I intend to attempt a series of such experiments, I must now content myself with the observations and facts which I have been able to collect*. From these I am of opinion, that the most immediate gradation from asphaltum (which is the last of the simple bitumens) into those which are compound, takes place in the substance called

I would be understood however to mean that the carbon is only relatively increased, in respect to the other ingredients, in a given quantity of these bitumens, and that it predominates in proportion to the dissipation of a certain portion of the hydrogen, which was originally necessary to the forming of the bitumen in conjunction with the carbon.

* This paper was written and read before I had seen the ingenious experiments which the celebrated Mr. Kirwan has published, in the last edition of his *Elements of Mineralogy*.—Vide vol. ii. p. 514.

JET.

JET.

JET is a substance well known to be of a full black, sometimes however inclining to brown. It is considerably harder and less brittle than asphaltum. It breaks with a conchoidal fracture, and the internal lustre is glassy. It has no odour except when heated, and it then resembles asphaltum. It melts in a strong heat, and, when burned, leaves an earthy residuum.

Wallerius considered jet as asphaltum which had become indurated by time, and Mr. Fourcroy is of the same opinion *. Others again have arranged it with the varieties of coal †. I am inclined however to believe, that it is neither asphaltum nor coal, but an intermediate substance which may be regarded as the first gradation from the simple bitumens into those which are compound. The matter of asphaltum undoubtedly enters into it in a large proportion, and has consequently stamped several of its characters upon it; but the increase of carbon, and of the extraneous or earthy matter which is intimately mixed or rather combined with it, has had so much influence, that the characters of coal are also in some measure apparent, and are rendered the more striking by the similarity of certain local circumstances which attend these two substances. The characters of coal are however by no means fully established in jet, but from this we pass immediately to another, in which these characters cannot be questioned.

This is the substance called

CANNEL COAL,

which is of a full black, of a smooth, solid, even texture; it breaks in any direction, and the transverse fracture is conchoidal. It

* *Elémens d'Hist. Nat. et de Chimie*, tom. iii. p. 456.

† *Widenmann's Handbuch der Mineralogie*, p. 628.

burns

burns well, and is so compact that it is often employed, like jet, to be formed into trinkets.

The great resemblance which cannel coal has to jet in many of its properties, induces me to regard it as the next gradation of the compound bituminous substances, and as the leading variety of coal from which the others follow according to the degree of their bituminous character.

The limits of this paper will not allow me to enter into a circumstantial account of all the other varieties of pit-coal; neither is it necessary, after the gradations of asphaltum to jet, and of jet to coal, have been noticed. I shall not therefore describe the varieties of coal known by divers names in different countries, and even in different provinces, such as those called in England caking coal, rock coal, splent coal, &c. &c.; but shall only observe, that the pit-coals in general appear to be composed of bitumen intimately mixed, or rather combined, with various proportions of carbon and earthy matter; and according to the intimacy of the union, and the excess of one or other of the ingredients, so the compound possesses more or less the characters of perfect coal, or, by various shades, passes into certain earthy or stony substances, which, although impregnated with bitumen, do not merit the appellation of coal, and these also at length gradually lose the bituminous character*.

It is likewise worthy of notice, that the quantity of earthy matter does not appear to be the principal cause why pit-coals do not burn with the rapidity which is to be perceived in some other earthy substances impregnated with bitumen. For we may conclude, that

* From Mr. Kirwan's experiments it appears that carbon is a constituent principle of coal, and that the presence of it is a principal cause of those modifications which produce the species. It even seems chiefly to form the Kilkenny coal.—*Kirwan's Elements of Mineralogy*, vol. ii. p. 521.

the slow combustion of coal proceeds from the joint effects produced partly by the relative proportions of the bituminous, carbonaceous, and earthy ingredients, and partly by the more or less perfect degree of mixture which connects them together, and which degree of mixture, I believe, in many cases, nearly approaches to chemical union, if not actually so: when, therefore, the degree of mixture is so perfect as that every particle of bitumen is connected with much carbon or earthy matter, it is not surprising that the rapid combustible property of the former should be checked in a considerable degree; and, by a parity of reasoning, when the mixture is gross and imperfect, so that it consists of a stony or earthy substance, which has simply imbibed bitumen, it is natural to expect that the bitumen (although less abundant than in coal) should enter readily into combustion, which is vehement in proportion to the shortness of its duration; and this we find to be the case in many earthy substances, and loose sand-stones which are simply impregnated with bitumen.—To return, however, to the varieties of coal, I must observe, that, from the causes above-mentioned, the different characters and properties of coal appear to me to be produced. That in this manner, perfect pit-coal passes into schistose or flaty coal, and this again, by certain gradations, passes into the varieties of combustible or bituminous schistus, which also, by the gradual decrease of the bituminous ingredient, become at length confounded with the varieties of the common or argillaceous schistus.

We have a remarkable example of this in the gradations of bituminous schistus into argillaceous schistus, which are to be observed at Kimmeridge, on the coast of Dorsetshire, where a peculiar bituminous schistus is found, which is used as fuel by the inhabitants, and is improperly called Kimmeridge coal.

By the series of gradations which have been noticed in the foregoing

going pages, the simple bituminous substances appear to pass into those which are compound; and these also, by declining shades, at last pass into substances appertaining to the class of earths and stones.

In the compound bituminous substances the prevalent earthy ingredient is for the greater part generally, if not always, argillaceous; and although certain calcareous grits (such as the Portland stone*) as well as limestones and marbles are found impregnated with bitumen, yet I know not of any instance in which this happens to the degree requisite to form a combustible substance.

This cursory view of the simple bitumens, and of their combinations, would be sufficient as an introduction to the principal subject of this paper; but, to complete the series, I shall make some observations on the vegetable substances which contain bitumen, and shall afterwards mention the mixtures of bitumen with metallic oxides.

§ 4.

WHEN we consider the facts which apparently prove that vegetables have contributed principally to the formation of bitumen, we have every reason to expect that mixtures of vegetable matter with bitumen should frequently occur. But by the mixture of bitumen with the parts of vegetables, we understand the remains and parts of vegetables mixed and connected with the bitumen which they themselves have produced.

This seems to be the nature of the substance called

*The Portland stone, when recently broken in the quarries, emits a strong bituminous odour, like the bituminous limestone or stink-stone. It is also full of extraneous fossils, or at least the vestiges of them.

BITUMINOUS WOOD, as well as of TURF and PEAT.

BITUMINOUS or fossil wood is found in many places ; but in respect to that which is found at Bovey, near Exeter, and which is therefore called Bovey coal, there are some peculiarities which deserve to be mentioned. The Bovey coal is a dark brown, light, brittle substance, which in texture and other external properties much resembles wood which has been half charred. It is not found as scattered logs or trunks, but forms regular strata.

The pits are on a heath which is flat and sandy ; the stratum of sand is however but thin, after which a pale brownish grey clay is found mixed with quartz pebbles. This prevails to about six feet, at which depth the first stratum of the coal commences. The quality of this is however much inferior to that of the subsequent strata, which in all amount to seventeen, producing a depth of nearly seventy-four feet from the surface. Between each stratum of coal is a stratum of clay. The direction of the strata is from east to west, and the inclination or dip is from north to south. The inferior strata are thought to afford the best coal, and the coal is more solid and of a better quality towards the south. The thickest stratum of coal is from six to eight feet *.

The Bovey coal burns readily with a flame like half charred wood : it does not crackle, and, if but moderately burned, forms charcoal ; or if completely burned, it leaves a small quantity of white ashes exactly similar to those of wood. The smell of it when burning also resembles that of wood, with a faint disagreeable odour. It is certainly very remarkable that this substance should form regular strata, although it possesses the texture and most of the

* In the winter, twelve men can raise about 120 tons of this coal in a week, the whole of which is employed in a neighbouring Pottery.

properties of wood; and that these strata do not exhibit any of those irregularities on their surfaces, which might be expected, on the supposition that they were formed by the roots, trunks, and branches of trees long buried in the earth. It is also difficult to imagine wood to have been transported and deposited in this place at seventeen different periods, and yet it must be allowed that these strata have been formed by successive operations. I must confess, that after having twice visited and examined the spot expressly for the purpose, I still find myself utterly unable to offer any opinion upon the subject.

The characters of bitumen are but little apparent in the Bovey coal, and the superior strata even appear to have lost a portion of their combustible principle, while the inferior strata possess it. The lower parts also of these strata are more compact and more combustible than those parts which are immediately upon them*.

Another remarkable sort of fossil wood, which much resembles the Bovey coal, and in like manner is arranged among the bituminous woods, is that found in Iceland, which is called by the inhabitants *Surturbrand*. This is rather harder than the Bovey coal, but in every other respect is the same. It also forms strata many feet in thickness; but it is very extraordinary that these strata appear to be formed of trunks of trees, which, in their transverse

* At about 100 yards to the west of the pits, is a bog of considerable extent, where peat is cut, and decayed roots and trunks of trees are found, which do not, however, in the least approach to the nature of the Bovey coal. Whether this bog has been in any manner connected with the formation of the above-mentioned substance, I do not pretend to determine.

A yellowish brown compact substance, which in colour and fracture resembles ferruginous clay, is also found occasionally with the Bovey coal: it is brittle, and is highly inflammable; it melts like a bitumen, and emits a smoke which in smell resembles amber. This substance is but rarely found.

section, exhibit the concentric circles of their annual growth, with this difference, that the trunks have been so compressed as to be nearly flat, so that the circles appear like parallel lines connected at their extremities by a short curve.

I did not observe such an appearance at Bovey; but this would depend upon the position of the trunks of the trees, in respect to the section of the strata.

Chaptal *, Troil †, Bergman ‡, and many others, have been of opinion that the furturbrand is wood which has been charred by the heat of the lava. But I cannot discern why it should be supposed that it has been acted upon by fire, any more than that the Bovey coal has been subjected to the effects of the same agent. The qualities of the two substances are the same; and as (from Archbishop Troil's and Professor Bergman's account) the furturbrand is stratified, I think we may venture to pronounce that the circumstances

* *Elements of Chemistry*, vol. iii. p. 199.

† *Von Troil's Letters*, p. 43.

‡ Quid de ligno fossili Islandiæ sentiendum sit, gnaro in loco natali contemplatori decidendum relinquimus. Interea, ut cum Vulcani operationibus nexum credamus, plures suadent rationes, quamvis huc usque modum ignoremus, quo situm texturamque adquisiverunt hæc strata. Scilicet truncis arborum perquam crassis constant, qualis in Islandiâ nullibi reperiuntur, et ne quidem hoc tempore crescere posse videntur. Hi situ horizontali in stratis multorum pedum crassitie congesti sunt et petroleo plus minus penetrati, non jam molli, sed optimè indurato, a quo tam nigrorem, quam flammæ sub deflagratione qualitatem mutantur. Sed quod in primis attentionem meretur, est truncorum in lamellas planas compressio.

Ponamus truncum arboris cujusdam transversim sectum, hinc, uti notum est, figuratur in orbem rediens circiter circularis, quæ omnia monstrat annotina incrementa, extimo propemodum parallela. Fingamus jam talem sectionem in tenuem laminam compressam, et veram habebimus ligni fossilis, de quo heic agitur, ideam; nam in magnis hujus materiæ frustis, transversim sectis, quemlibet annotinorum orbium visu persequi-
liset, ita plerumque coactum, ut duas lineas fere parallelas exhibeat, quarum extrema
brevi

stances under which they are found, are also similar*. The whole, therefore, of the opinion in favour of fire, appears to rest on the volcanic nature of Iceland; but it surely would be going too far were we to ascribe to fire all the phænomena which are observed in volcanic countries.

Bovey coal, like the *surturbrand*, resembles half-charred wood; and I will allow, and indeed am disposed to believe, that it is in a state nearly similar; but from this it does not follow that fire has been the cause.

Carbon is known to be one of the grand principles of vegetables, and also as that which is the most fixed, excepting the small portion of the earths contained in them. As a fixed principle, carbon appears to form, in great measure, the vegetable fibre; and after a certain degree of combustion, (by which the other principles have been dissipated,) it remains, and the particles of it keep the same arrangement which they possessed when the vegetable was complete. If, however, the combustion has been carried on with the

brevi flexura sunt adunata.—Quæ autem immanis requiritur vis, ut truncus cylindricus ita complanetur? Nonne antea particularum nexus putredinis quodam gradu fuerit relaxatus? Certe, nisi compages quodammodo mutatur, quodlibet pondus incumbens huic effectui erit impar. Cæterum idem observatur phænomenon in omni schisto argillaceo.

Orthoceratitæ, quæ in strato calcareo conicam figuram perfectè fervant, in schisto planum fere triangulare compressione efficiunt. Idem valet de piscibus, conchis, insectisque petrefactis. Causa adhuc latet, sed in utroque casu sine dubio eadem est, et digna quæ exploretur. Observatu quoque dignum est, quod idem reperiatur effectus, quamvis stratum calcareum sub schisto collocatum sit et majori ideo pondere comprimente onustum.—*Bergman de Productis Vulcaniis Opuscula*, tom. iii. p. 239.

* “It is found (the *surturbrand*) in many parts of Iceland, generally in the mountains, in horizontal beds; sometimes more than one is to be met with, as in the mountain of Lack in Bardestrand, where four strata of *surturbrand* are found alternately with different kinds of stone.”—*Troil's Letters*, p. 42.

free access of air, the carbon enters into combination with oxygen and caloric, and forms carbonic acid.

We have many examples in which carbon is formed or rather liberated from those substances with which it was combined in vegetables; and these are now explained as effects similar to those of combustion, although fire has not been the cause. In both cases the carbon has been freed from the more volatile principles; and under circumstances not favourable to the union of carbon with oxygen, the former must necessarily remain more or less undiminished.

During the combustion of vegetable matter, the more volatile principles contained in the vegetable fibre (which with carbon also form the resinous and other similar substances) appear to be first separated; and in proportion to this separation, the other more fixed substance, which we call carbon, is developed.

Thus, by the progress of combustion, wood becomes brown, and afterwards black; so that the state of the wood shews the degree of combustion to which it has been subjected, or, in other words, how far the separation of the other principles from carbon has been effected.

Combustion is therefore a species of analysis by which the principles of vegetables are separated, according to their affinities, and according to their degree of volatility. By this operation hydrogen and azote (if it be present in the vegetable) are first disengaged and form new combinations, while the carbon is the last which is acted upon; so that unless a sufficient quantity of oxygen be present, it remains fixed and unchanged.

But the same separation of the vegetable principles happens whenever vegetables in the full possession of their juices are exposed to circumstances which favour the putrid fermentation.—As in combustion,

combustion, so by the progress of putrefaction does the vegetable lose its colour, become brown, and afterwards black; at the same time a gas is discharged, which is composed of hydrogen, azote, and carbonic acid.

When combustion is long continued with the free access of air, the whole of the carbon is dissipated in the state of carbonic acid; but in the process of putrefaction a considerable portion of carbon commonly remains even long after the putrid fermentation has ceased. Although, therefore, it is as readily developed by putrefaction as by combustion, it is not, however, when liberated from the other principles, so speedily dissipated by the former as by the latter process.

According to the degree of combustion within certain limits the carbon is more or less apparent, and the like prevails according to the degree of putrefaction; so that whenever the causes which have promoted this species of fermentation have ceased, the vegetable substance will remain with more or less of its first principles, and with more or less visible carbonic matter, according to the degree of putrefaction which has prevailed, and the vegetable substance will consequently have the appearance and properties of wood which has been charred more or less.

To this cause, therefore, I am inclined to attribute the formation and appearance of the Bovey coal and furturbrand; and I believe that the portion of oily and bituminous matter, which I have obtained from them by distillation, is nothing more than the remainder of the vegetable oils and juices which have been partly modified by mineral agents*.

The

* "Coal not only forms the residuum of all vegetable substances that have undergone a slow and smothered combustion, that is, to which the free access of air has been prevented,

The characters of bitumen are much more apparent in turf and peat, than in the greater part of the fossil woods. Turf is well known to be composed of the parts of vegetables, such as small roots, twigs, &c. mixed with a portion of petroleum; and peat is the same, excepting that it generally contains more of earthy matter, or that the vegetables have undergone a more complete decomposition.

The boggy nature of the places in which they are found, proves that a certain degree of maceration is necessary to form the bituminous matter which they contain; and I have already noticed, that every fact appears to demonstrate, that the bitumen is a product of those vegetables, the remains of which constitute the other ingredient of turf and peat.

The different proportion of vegetable matter, of bitumen, and of earth, together with the different state of the bitumen, as well as the degree of perfection respecting the formation of it from the vegetable principles, contribute to alter the properties and characters of the compound, and thus produce varieties. It is believed that these substances have been materially concerned in the formation of pit-coal, and some eminent mineralogists maintain that there is an uninterrupted series which connects the varieties of turf and peat with those of coal*.

§ 6.

vented, but also of all putrid vegetable and animal bodies: hence it is found in vegetable and animal manures that have undergone putrefaction, and is the true basis of their ameliorating powers; if the water that passes through a putrefying dunghill be examined, it will be found of a brown colour, and if subjected to evaporation, the principal part of the residuum will be found to consist of coal. All soils steeped in water communicate the same colour to it in proportion to their fertility; and this water being evaporated, leaves also a coal, as Messrs. Hassenfraz and Fourcroy attest."—*Kirwan on Manures*, p. 154, Vol. v. of *The Transactions of the Royal Irish Academy*.

* Man findet in der natur einen ununterbrochenen übergang von dem rasen und papiertorf

§ 5.

LITTLE need be said concerning those mixtures of bitumen with metals or their oxides which are sometimes called the bituminous ores of mercury, copper and iron, for they should rather be arranged with the adulterated or impure bitumens. Few of them contain the metallic ingredient in a proportion sufficient to cause the compound to be worked as an ore; and the only exception with which I am acquainted, is the substance found at Idria, in Carniola, composed of mercury mixed with bituminous matter, a quintal of which, according to Mr. de Born, affords from fifteen to twenty pounds of mercury*.

§ 6.

FROM the preceding observations it will appear, that although I have first mentioned naptha in order that I might be better understood in respect to the degree of connection prevailing between the bituminous substances, yet, to have followed them from their origin and the period of their formation, I should rather have begun with those substances which most clearly point out how much the vegetable kingdom has contributed to the production of them, with the probable occasional concurrence of animal substances.

That the latter have contributed in some measure to the forming of bitumen, we can only infer from the vestiges and exuviae of animals, which so commonly accompany bituminous substances;

papiertorf durch den moor oder sumpftorf in den pechtorf, und von diesem in die braun schiefer und pechkohle.—Widenmann, p. 630.

* *Catalogue de la Collection des Fossiles de M^{lle}. de Raab*, tom. ii. p. 294, 348, & 400.

but no doubt can be entertained in respect to vegetables, for it appears that bitumen is formed from them by long maceration, and by other processes at present unknown to us :

That when certain portions of vegetable matter remain undecomposed, and are mixed with the petroleum thus produced, the varieties of turf and peat are formed :

That wood in general contributes to the production of bitumen ; but does not seem to retain it, after the formation of it, in so considerable a proportion as the foregoing substances :

That the bituminous matter thus formed, and occasionally separated, is in different states according to the degree of inspissation :

And lastly, with various proportions of carbonic and earthy matter, it forms jet, coal, and bituminous schistus ; and with metallic substances it produces those compounds called bituminous ores.

§ 7.

ABOUT the year 1786 a new species of bitumen was discovered near Castleton, in Derbyshire, which much resembles, in elasticity and colour, the substance known by the name of cahout-chou, or Indian rubber.

Mr. de Born was, I believe, the first who mentioned it* ; but as he appears to have known only one variety of this singular substance, I am induced to hope that a description of many other varieties, which have since been found, will not be unacceptable to this Society.

The elastic bitumen, which resembles the cahout-chou, was first discovered in the cavities of a vein in the lead-mine called Odin, which is near the base of Mantor, to the north of Castleton. The

* *Catalogue de la Collection de M^{lle}. de Raab, tom. ii. p. 77.*

ore of this mine (which is supposed to be one of the most ancient in England) is galena, accompanied by fluor, calcareous and heavy spars, quartz, blende, calamine, selenite, asphaltum, and the elastic bitumen, although the latter is now rarely found*. Another species of the elastic bitumen has within about three years been found in a neighbouring rivulet; but I shall not at present notice it, as I intend first to describe the varieties of that which was first discovered, and which resembles the cahout-chou. In order to do this with more perspicuity, I shall describe the specimens belonging to my collection, according to the mode in which I have arranged them.

SPECIES THE FIRST.

A, No. 1.

ELASTIC bitumen of a yellowish brown colour, part of which is almost liquid like petroleum, and adheres to the fingers; the other part is of a darker colour, of a mammillary form, does not adhere to the fingers, and is soft and elastic. This is on a grey bituminous limestone, with white calcareous spar in the figure of hexaedral pyramids, forming that which is called the dog-tooth spar.

A, No. 2.

Bitumen of a yellowish brown, partly liquid, and partly elastic, which, however, adheres to the fingers; on pale grey limestone, with crystals of white fluor spar, blende, and galena.—On another part of the limestone are some globules of bitumen of a reddish brown, perfectly hard and brittle.

* I am indebted to the ingenious Mr. White Watson, of Bakewell, for much information respecting the local circumstances which attend this bitumen.

A, No. 3.

Dark brown bitumen of a stalactitical form, hard, but in some degree elastic.

A, No. 4.

Bitumen of a reddish brown, in the form of globules, some of which are elastic, and others hard: on brownish-grey limestone, accompanied by crystallized white fluor, dogtooth calcareous spar, and pyrites in small crystals, some of which are on the surface of the globules of bitumen.

A, No. 5.

The same of a darker brown, of a stalactitical form, hard and brittle; on pale brown calcareous spar, impregnated with bitumen.

A, No. 6.

Bitumen of a dark reddish brown, very hard; on pale brown sparry stink-stone, with grey limestone, in which are some coralloides.

A, No. 7.

Bitumen of a dark yellowish brown, elastic, but very soft, so that it adheres to the fingers.

A, No. 8.

The same thinly spread over grey sparry stink-stone.

A, No. 9.

Bitumen of a brownish olive colour, which becomes reddish brown by the air, but when opposed to the light it appears semi-transparent,

transparent, and of a yellowish brown inclining to orange. It is soft, very elastic, and (when recently cut) adheres to the fingers.

A, No. 10.

The same of a darker brown, and harder in a small degree. The specific gravity of this specimen is 0,9053; water being estimated at 10,000 at temp. 60°.

A, No. 11.

Bitumen of a dark brown, harder than the former. This exactly resembles the cahout-chou in the degree of elasticity, and in the property which it possesses of removing the traces of black-lead.

A, No. 12.

The same, but rather harder.

A, No. 13.

The same of a blackish brown, which is slightly elastic when the weather is warm, but is brittle when cold.

A, No. 14.

The same of a blackish brown, nearly black, which scarcely possesses any elasticity; it breaks, and resembles asphaltum in lustre, colour and fracture.

A, No. 15.

The same of a reddish brown, perfectly hard and brittle. The characters of asphaltum are complete in this specimen.

The specific gravity is 10,233.

The other species of elastic bitumen, which I shall distinguish by
the

the letter B, has been found during the last three years in a rivulet which runs at the base of Mamtor, from West to East, at a small distance from Odin mine.—The varieties of it, in my possession, are as follow :—

SPECIES THE SECOND.

B, No. 1.

ELASTIC bitumen, which, recently cut, exactly resembles fine close cork in colour and texture, but, by the air, in a few days it becomes of a pale reddish brown.—This forms a thin coat, which completely covers a mass of elastic bitumen, which is soft, and of a brownish olive colour, like A, No. 9.

B, No. 2.

The same, excepting that the coat or crust is much thicker.

B, No. 3.

The same, but the coating is thicker than that of No. 2, and the brownish olive-coloured bitumen much less in quantity.

B, No. 4.

The same, excepting that the greater part of the mass resembles cork, so that only a very small nucleus of the brown bitumen remains*.

B, No. 5.

The same, excepting that the bitumen, which is coated, is in the state of asphaltum.

The specific gravity of this specimen is 0,9881.

* One of the specimens in my possession, similar to B, No. 4. weighs between 13 and 14 pounds.

B, No. 6.

Elastic bitumen, the whole mass of which resembles fine cork.—
The specific gravity is 0,9748.

B, No. 7.

The same, but friable, and apparently passing by decomposition into an ochraceous coloured powder.

THE varieties of the first species of the elastic bitumen, or that which is like the cahout-chou, evidently appear to be formed from a naptha or petroleum, which, like that which produces the other simple bituminous substances formerly mentioned, is susceptible of various degrees of inspissation.

All the varieties of the first species, from No. 1, to No. 15, may be regarded as thus formed, for in these we can trace all the modifications comprehended between petroleum and asphaltum; with this difference, that the intermediate modifications of this species have the remarkable property of elasticity, which is the most complete in the variety which occupies the middle place between petroleum and asphaltum.

The second species B, or that which resembles cork, appears so different from that marked A, that it is not at first easy to conceive how they are connected, or at least the difficulty must appear great to those who have only seen specimens of each species complete in their respective characters. But, from an attentive examination of many specimens, and particularly of those which I have described, I am convinced that the varieties of the species B are only modifications of the species A, produced probably by long maceration in the water of the rivulet in which this species is found, to the effects of which we may, with some appearance of reason, add the vicissitudes

vicissitudes of the seasons, of air, and of the weather in general, as well as those of reiterated moisture and dryness occasioned by the rise and fall of the water of the rivulet; and what seems to corroborate this opinion is, that the substance, like cork, incrusts the species A, and appears to be only a change which has penetrated deeper into the substance of it in proportion to the duration of the causes which I have mentioned, so that at length the original substance no longer remains in its primitive state. I do not believe, however, that this change arises from any alteration in the constituent principles, but merely from a partial and minute disunion or disintegration of the particles of the original substance, as both species melt into one which is perfectly similar. I must also add, that the species A burns easily, and with rapidity; but the species B burns with some difficulty, and crackles as if it had imbibed a quantity of water.

I have remarked, when the different varieties of the elastic bitumen were melted, that they completely lost the elastic property, and a quantity of air or gas appeared to be disengaged, particularly from the species B. I also observed, that the substances which remained after this operation, corresponded, in respect to consistence, with those which had been employed, as the following Table will shew:—

A, No. 7 and 8. ... produced a thick liquid petroleum, not apparently different from that which is commonly known.

A, No. 9. produced a thicker petroleum, approaching to mineral tar.

A, No. 11 and 12. produced mineral tar.

B, No. 6. produced the same, approaching to mineral pitch.

A, No. 13. produced mineral pitch.

A, No. 14 and 15. did not suffer any change, but remained as at first, with all the characters of asphaltum.

From what I have related, I suspect that the elastic property is occasioned by the interposition of very minute portions of air or some other elastic fluid between the parts of the bitumen, and that this takes place by reason of some unknown cause at the time of formation; but when these bitumens are melted, the elastic fluid is liberated, and the mass loses that fine spongy texture which I suspect to have been the cause of the elastic property*.

Derbyshire is well known as a country which exhibits, in the most striking manner, the remarkable changes which our globe has suffered. In every part of it, the most indisputable evidences appear of some great and extraordinary revolution; and there is not any place where extraneous fossils, such as the remains and impressions of vegetables and animals, are more abundant.

Bitumen, in other countries, is most commonly found where these present themselves; and, in like manner, there are few countries which abound so much with bitumen as Derbyshire.

Whoever has examined the limestone rocks about Matlock, and most other places in this county, must be convinced of the truth of this assertion.

The limestone and calcareous spars also, where the elastic bitumen is found, are, for the greater part, in the same state; so that no doubt can be entertained but that this bitumen has had the same origin as those which are more generally known; and it would

* The elastic bitumen, A, No. 9. when digested in sulphuric ether in a temperature of about 55° , is partly dissolved. The solution is yellowish brown when opposed to the light; but when otherwise viewed, is like the bitumen, that is, of a brownish olive colour. By spontaneous evaporation, the etheric solution leaves a yellowish brown bitumen, which is totally devoid of elasticity. The undissolved portion (like the cahout-chou under similar circumstances) is softened, and is much increased in bulk.

The species B, No. 6. cut into very thin slices, communicates a yellow tinge to sulphuric ether; in other respects it is but little affected.

undoubtedly have been confounded with them, had it not been discovered when passing from the liquid to the solid state.

The elementary principles of bitumen are, hydrogen, carbon, sometimes azote, and probably some oxygen, which, by its action on the other principles, tends to form the concrete bitumens, and also produces that portion of acid obtained by chemical operations. These same principles, hydrogen and carbon, constitute the vegetable oils and resins; and the same, with some azote, form the oils and grease of animals. Now it is known that very small changes in the respective proportions of these ingredients, and in the circumstances which attend the combination of them, will cause considerable variations in the nature of the products; and in like manner, it appears very probable, that when the organized bodies in their recent state, and in the full possession of the above-mentioned principles, have been buried in a situation where these principles have been long elaborated under certain favourable circumstances, and subjected to the action of mineral bodies; I say that it appears highly probable, that a new combination, which we call bitumen, may be formed, which, although different in some respects from the vegetable and animal products, still, however, retains many characters of those substances from the principles of which it has been formed.

HAMMERSMITH,

April 26, 1797.